53 MHz Pbar Feedforward Beam Loading Compensation
Joe Dey

Delay Line

Main Injector
Resistive Wall Current Monitor
Buffered Output Fan-out
MI60004

Main Injector
53 MHz Fan-out from MI60011

53 MHz
Feedforward
Downconvert
Module

Mini-Circuits
ZHL-6A
Amplifier

"I" Input

"I" Output

Mini-Circuits
BLP-30
Filter

Main Injector
53 MHz Fan-out from MI60011

53 MHz
Feedforward
Upconvert
Module

Merrimac
PMP-3R-53B
Phase Shifter
In
Out
Control

I:FFPHA
465 Card Curve
MI CAMAC
Crate $93

Mini-Circuits
TAK-5
Frequency
Mixer
R
L
I

I:FFAMP
465 Card Curve
MI CAMAC
Crate $93

Main Injector
53 MHz Fan-out
from MI60011
9 dBm

PDC-20-50
Splitter

3 ns

1 ns

PU RF In

FO RF In

I:FFTRG1

FT-50

Reset In

MI60021
CAMAC 377
Crate $93
Slot 18
Channel 0

Digital Delay Card
531 Buckets

Mini-Circuits
ZHL-32A
Amplifier

1dB

Trilithic
RA-534
0-11by 0.1 dB
Step Attenuator
Setting = 1.0 dB

Pbar

C

50 Ω

P

TTL Input

I:FF2AON
I:FF2AOF

MI60021

HP 33311B
Coaxial Switch

Mini-Circuits 24 Way-0 degree
Power Splitter
1-200 MHZ

1 2 3 4 5 6 7 24

50 Ω 50 Ω 50 Ω 50 Ω 50 Ω 50 Ω 50 Ω

26 λ
1/2 Heliax
Station #1

LLRF
Fan-out

Amplitude
Modulated
53 MHz

Mini-Circuits
PSC-2-1
Splitter

0.25 V
Setting

Mini-Circuits
PLS-1
Limiter

Mini-Circuits
ZFSC-2-1
Splitter

Mini-Circuits
ZFL-1000VH2
Amplifier

Intech
4 kW Solid State
Amplifier

Fundamental
Feedback
Module

Delay Line

Upstream Gap Monitor
100,000 / 1

Downstream Gap Monitor
100,000 / 1

HP 89441A
Vector Signal Analayzer

Mini-Circuits 24 Way-0 degree
Power Splitter
1-200 MHZ

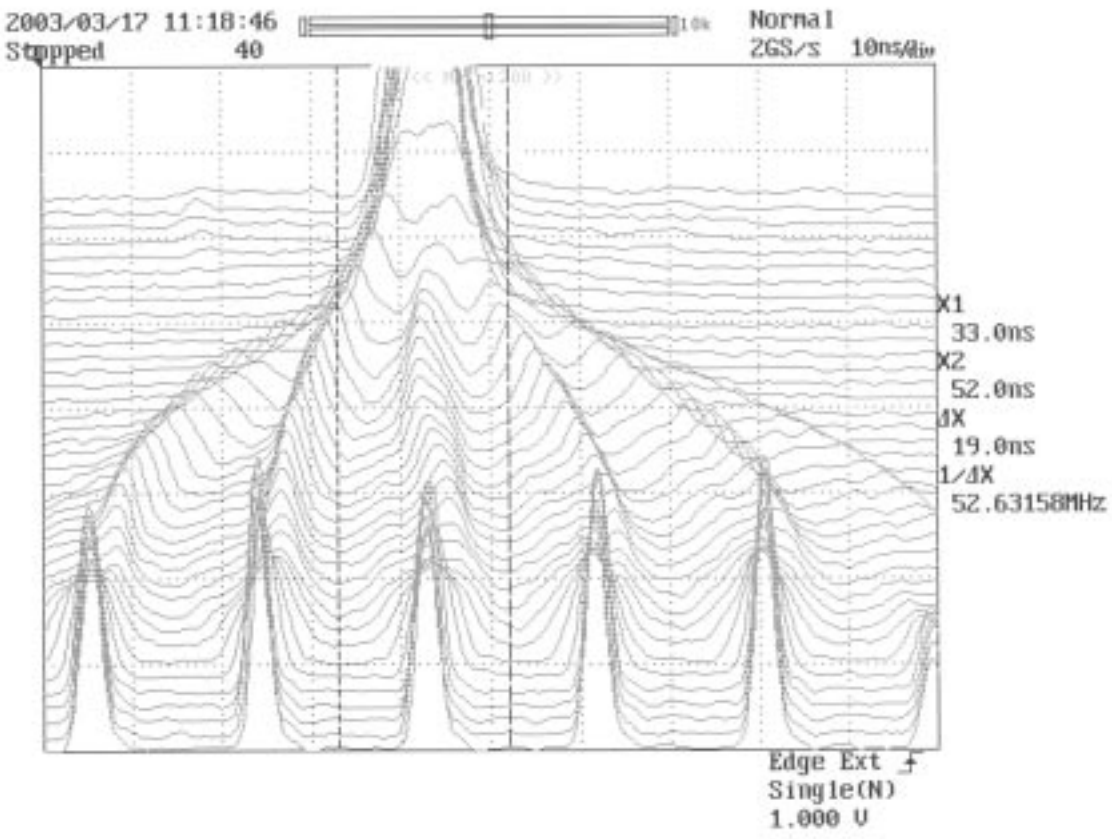
1 2 3 4 5 6 7 24

50 Ω 50 Ω 50 Ω 50 Ω 50 Ω 50 Ω 50 Ω

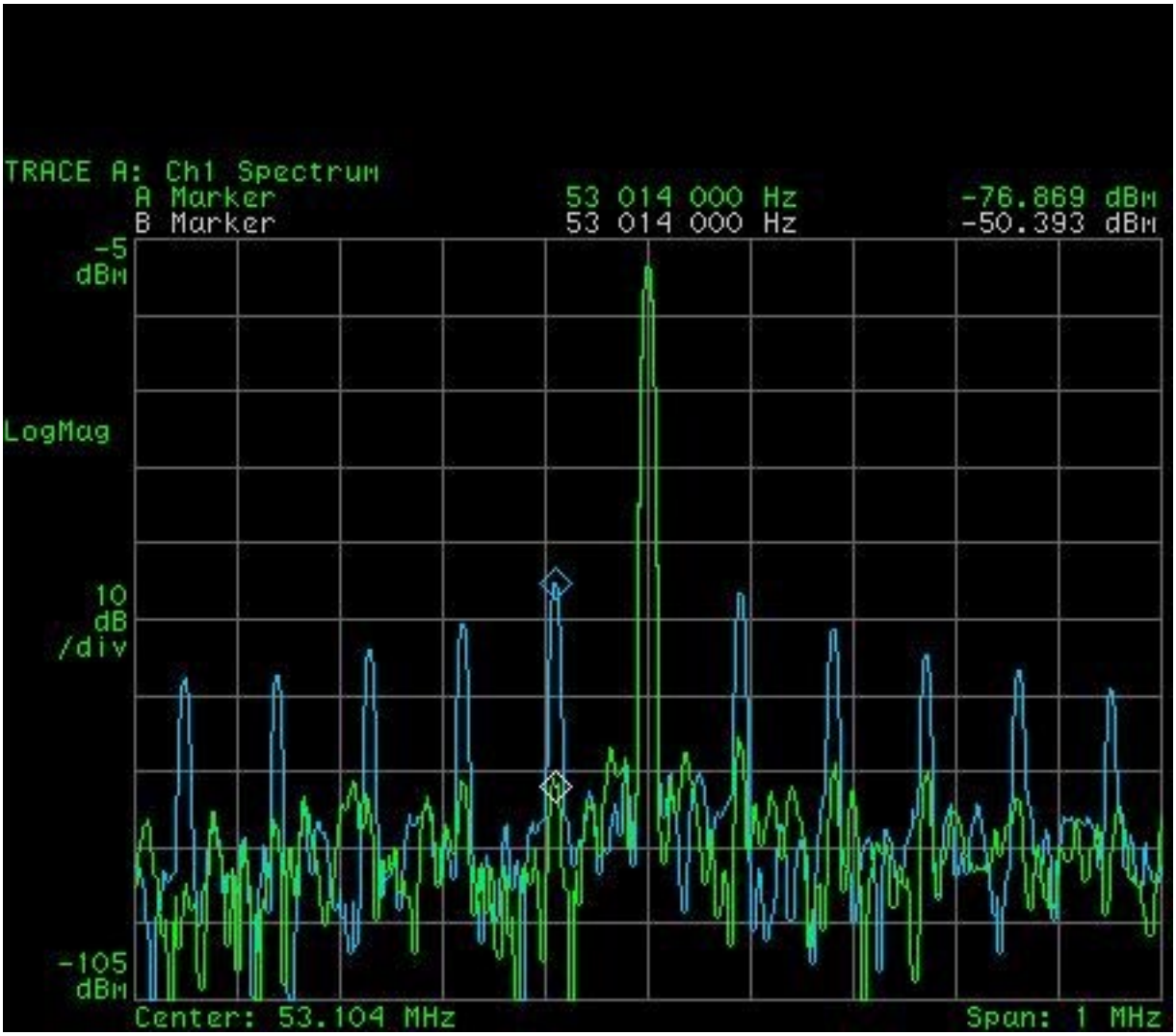
4 λ
1/2 Heliax
Station #1

Proton Coalescing

Using a combination of Feedforward and Feedback Beam Loading Compensation (BLC), we were able to increase Proton Coalescing efficiency by 5%. The day-to-day reliability of Proton Coalescing has been greatly enhanced by these improvements.



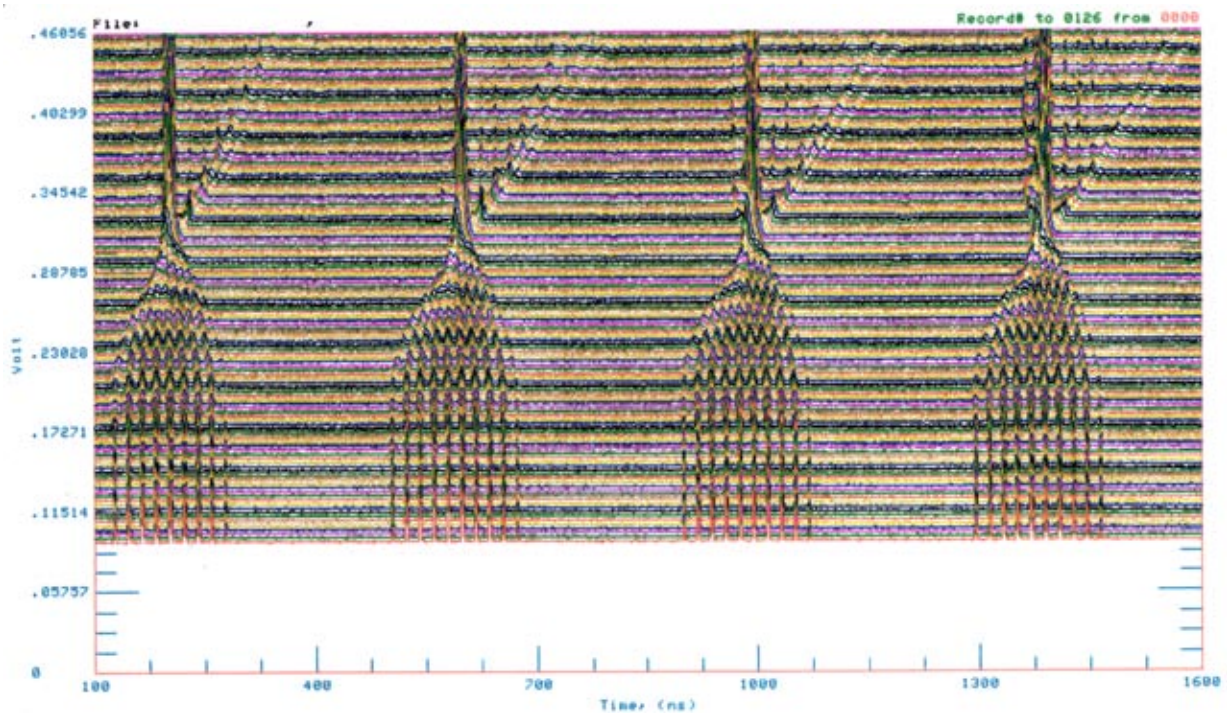
Proton Coalescing of 283E9 Protons



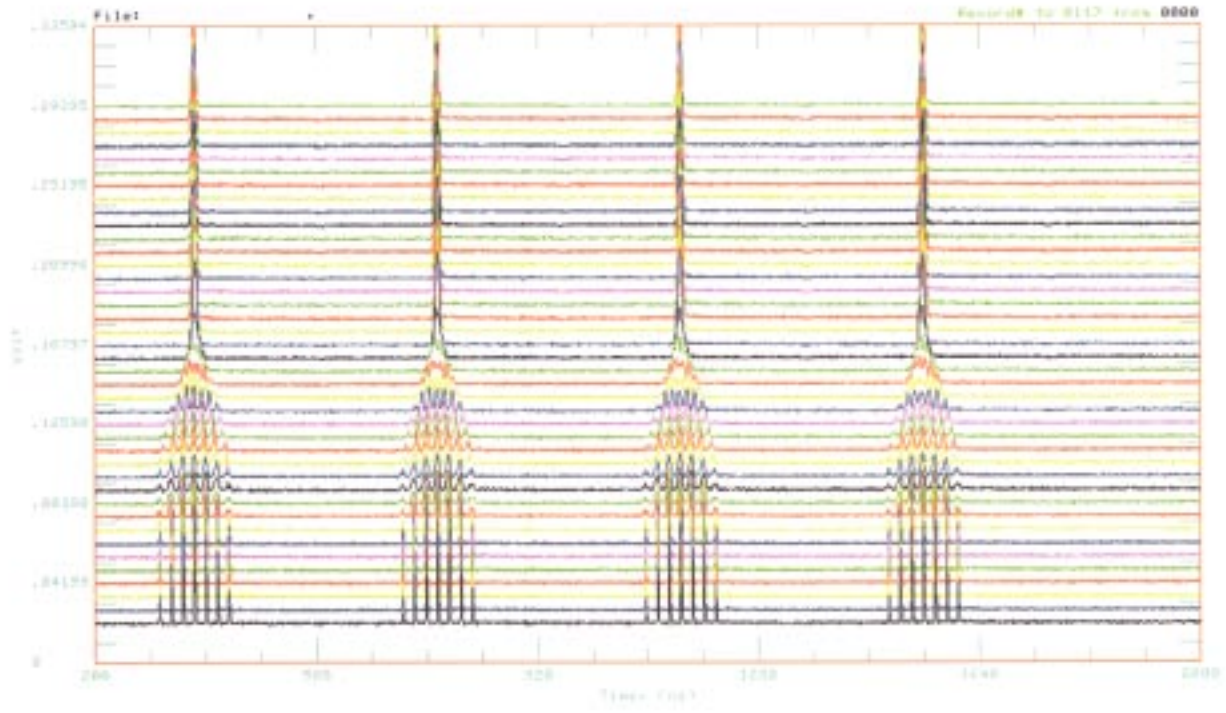
Beam Loading Compensation on Proton Coalescing

Pbar Coalescing

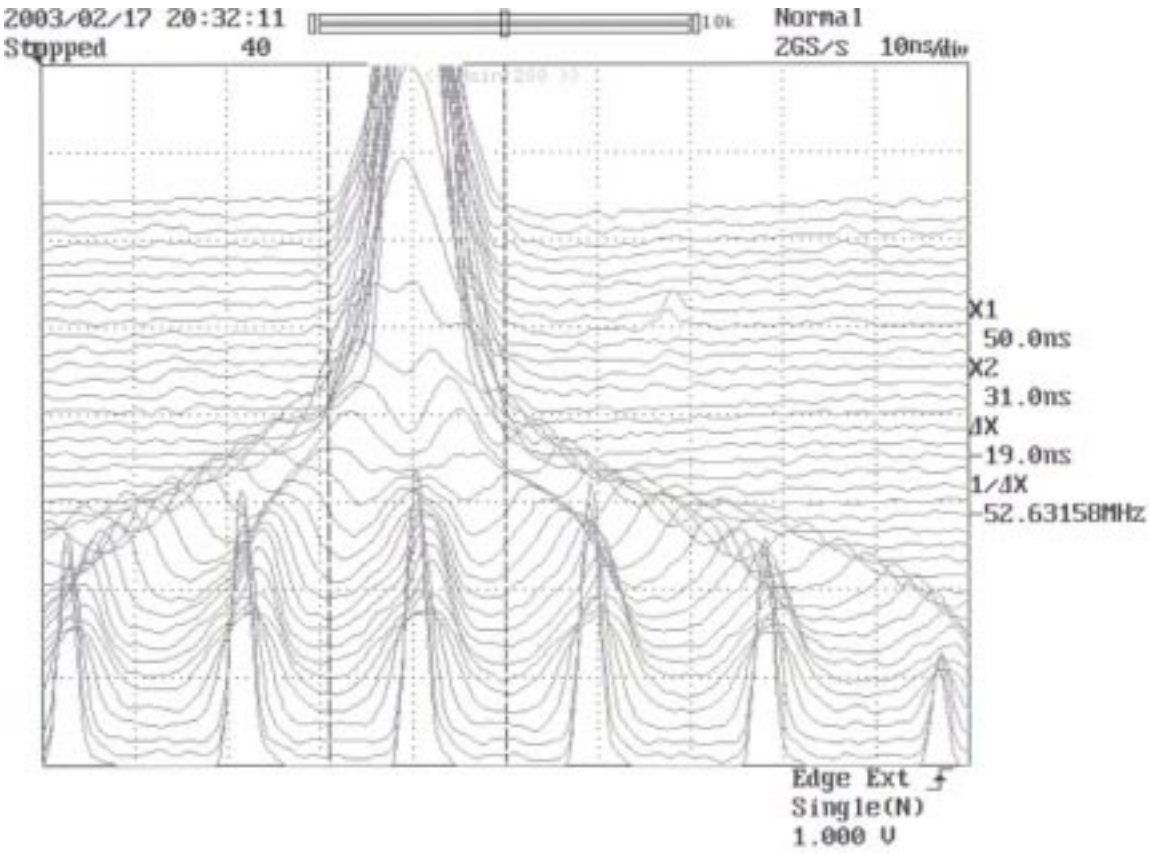
Applying Beam Loading Compensation on Pbar Coalescing, the multi-bunch alignment problem was solved and the efficiency rose from 75% to 90%.



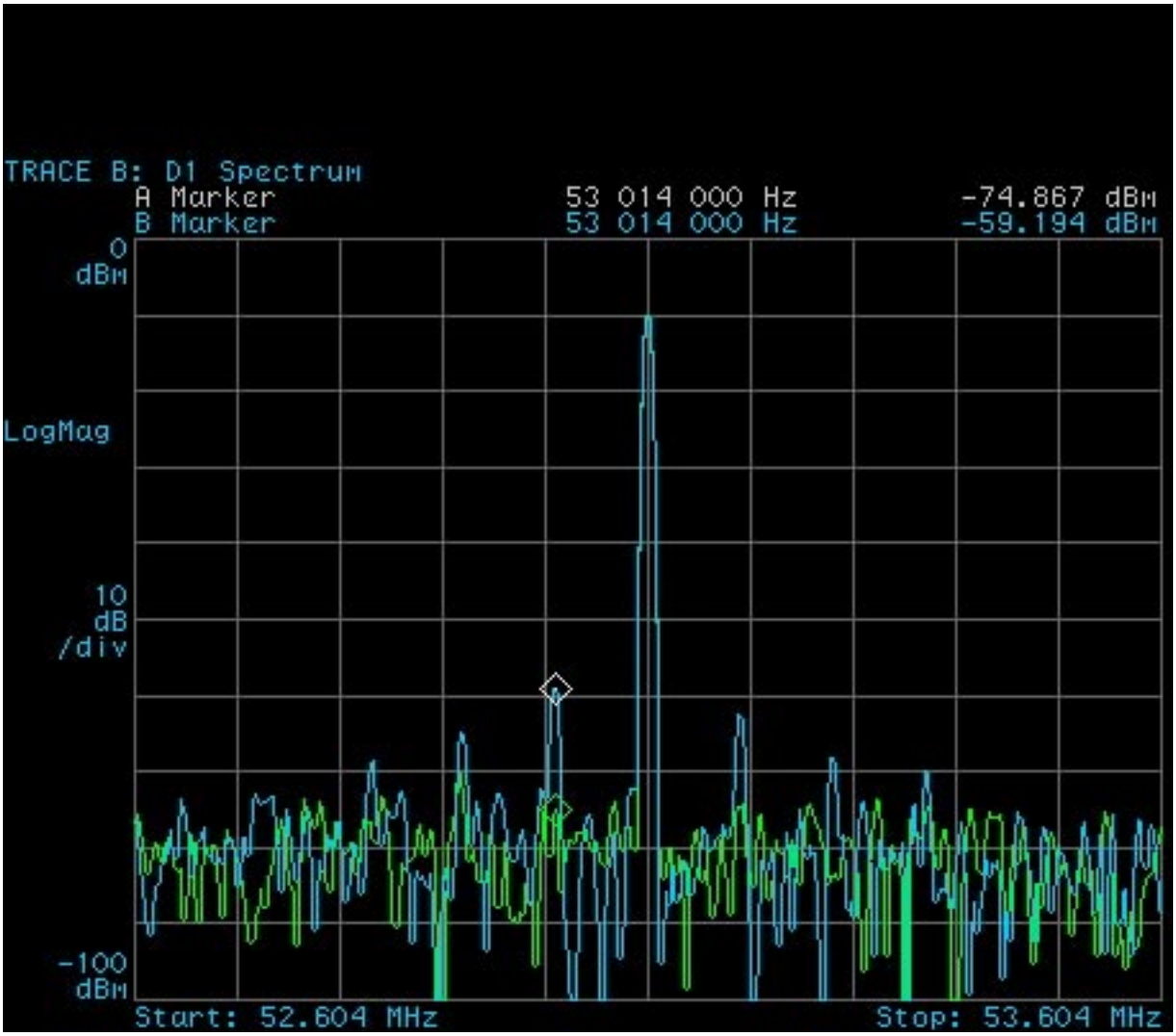
Pbar Coalescing with Feedforward BLC Off



Pbar Coalescing with Feedforward BLC On

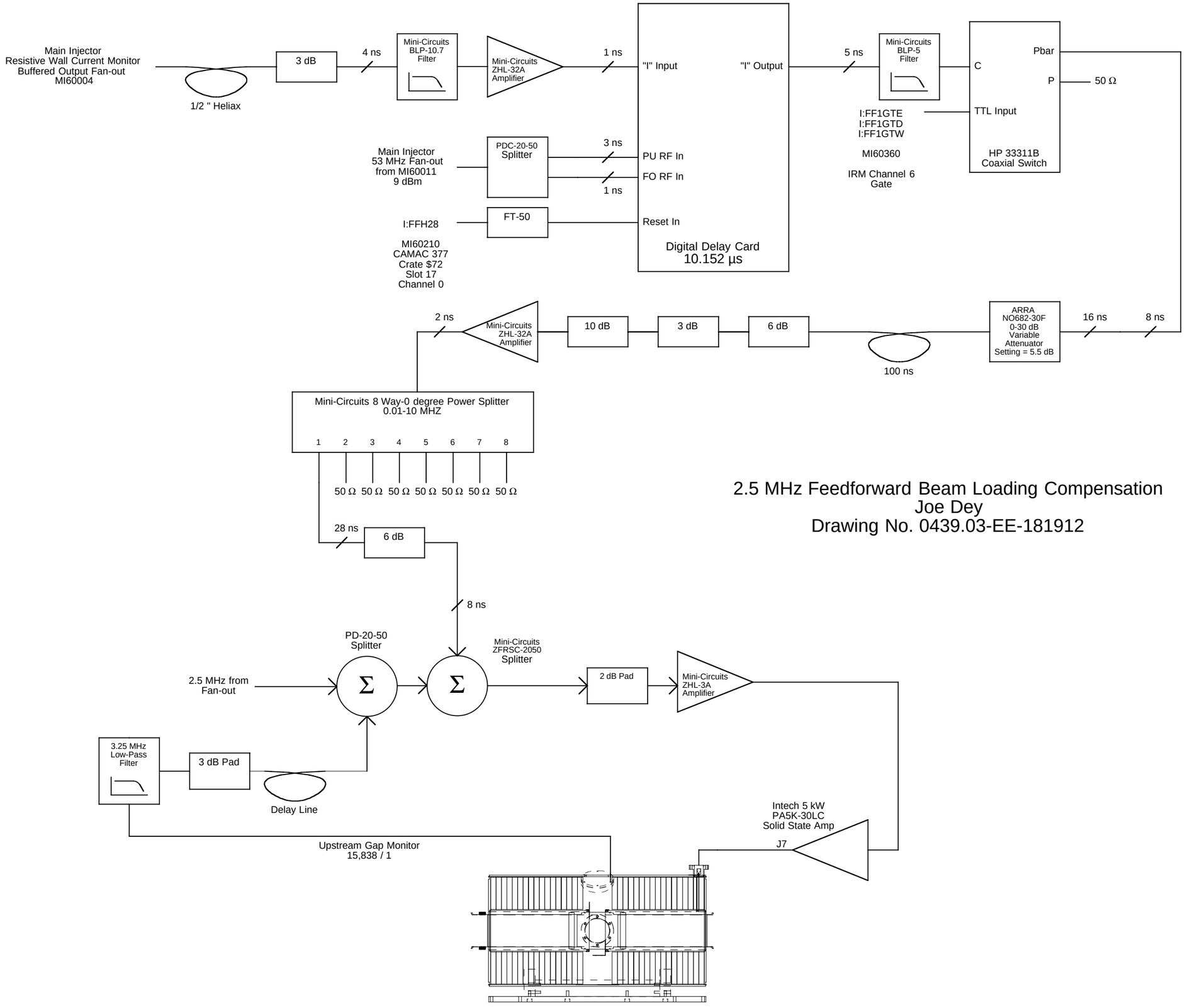


Second Bunch of Multi-bunch Pbar Coalescing on Store 2236, Shot #5



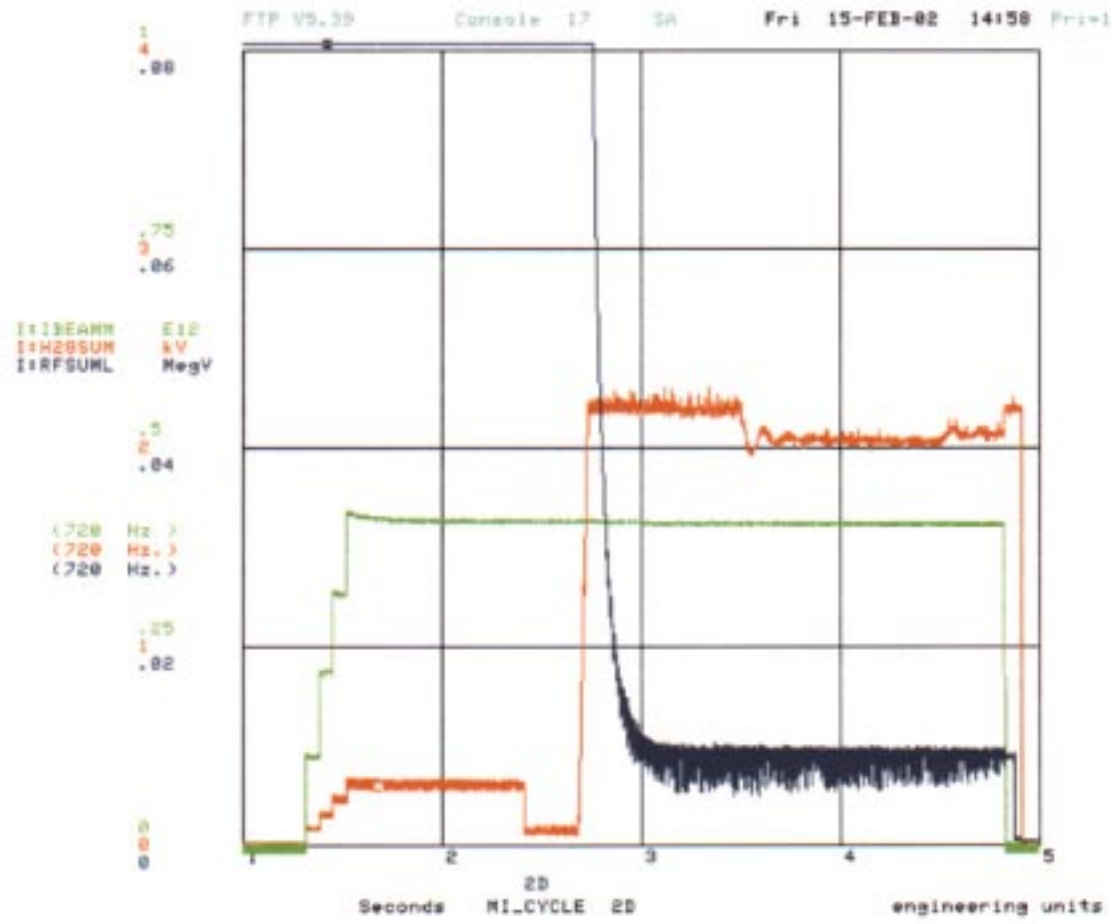
Beam Loading Compensation on Multi-bunch Pbar Coalescing

2.5 MHz Feedforward Beam Loading Compensation
Joe Dey
Drawing No. 0439.03-EE-181912

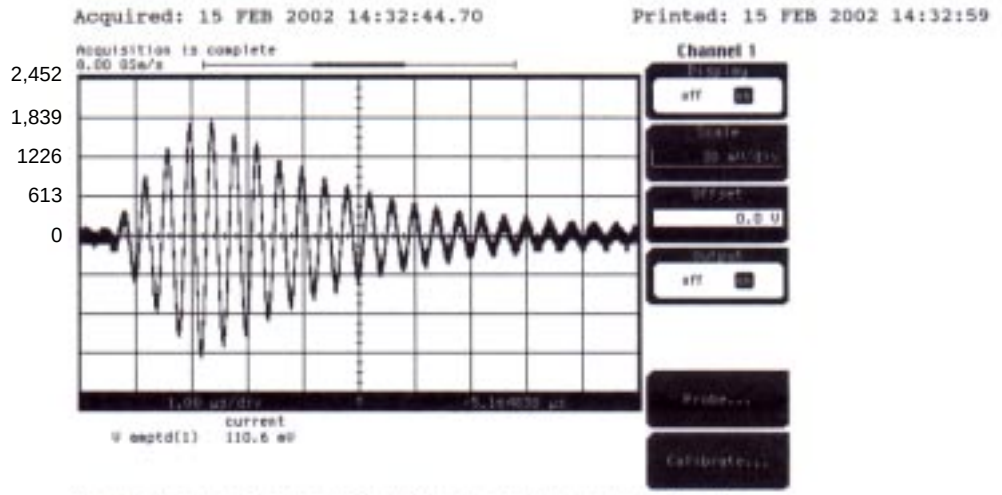


Recycler Transfers

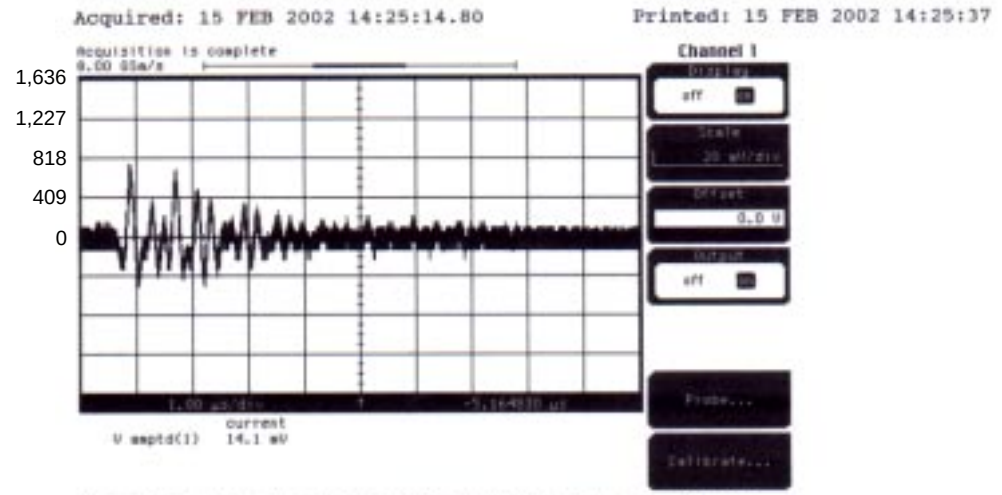
Because of the low 2.5 MHz RF Voltages (2 kV) required during the multi-bunch Pbar transfers from Recycler to Main Injector, Beam Loading Compensation is essential. Both Feedback and Feedforward Beam Loading Compensation have been implemented on the Main Injector 2.5 MHz Cavities.



Coalescing Cavities Gap Monitor (I:H28SUM) with and without 2.5 MHz Feeedforward BLC



Recycler Multi-buch Injection with 2.5 MHz Feedforward BLC Off

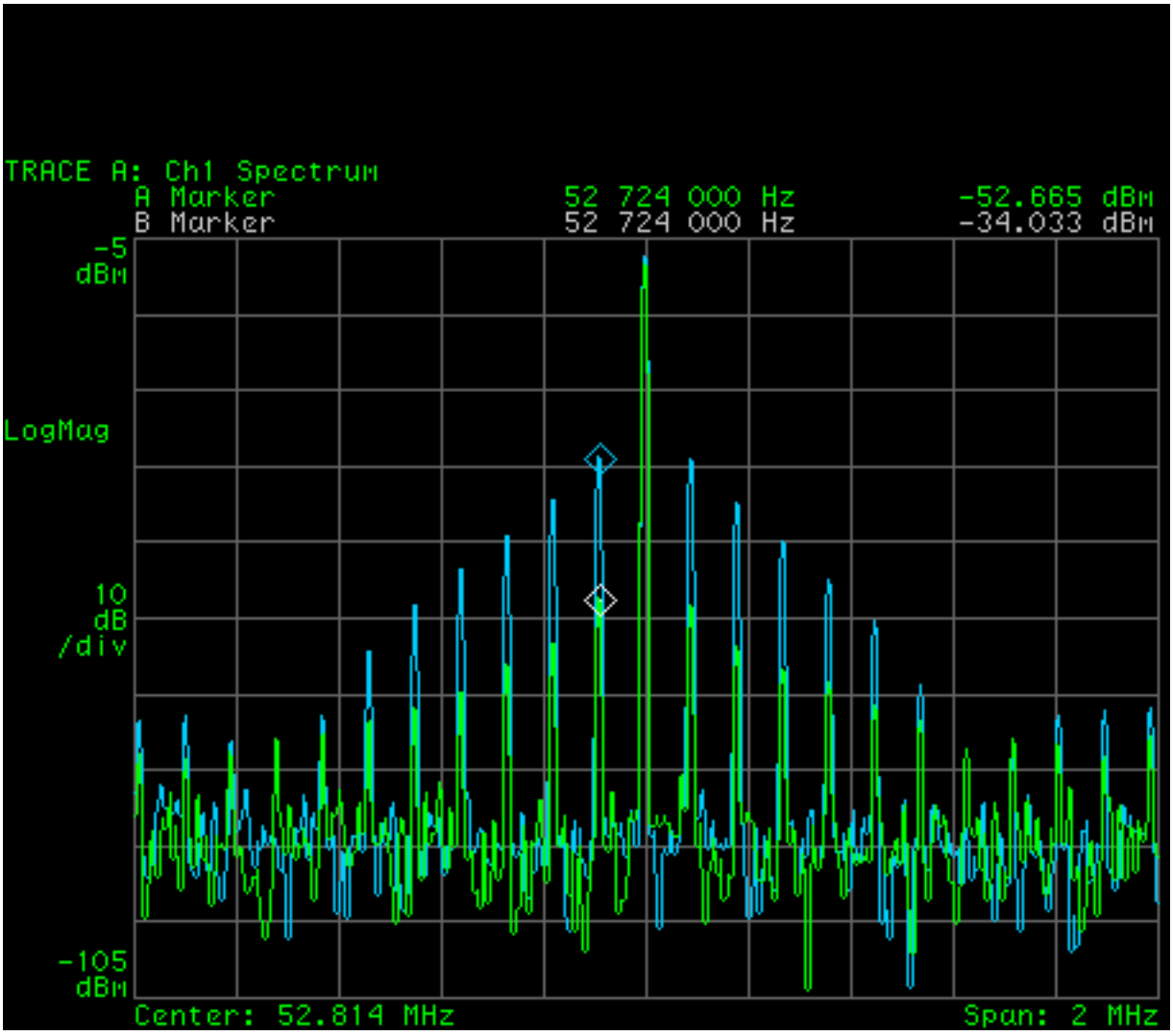


Recycler Multi-buch Injection with 2.5 MHz Feedforward BLC On

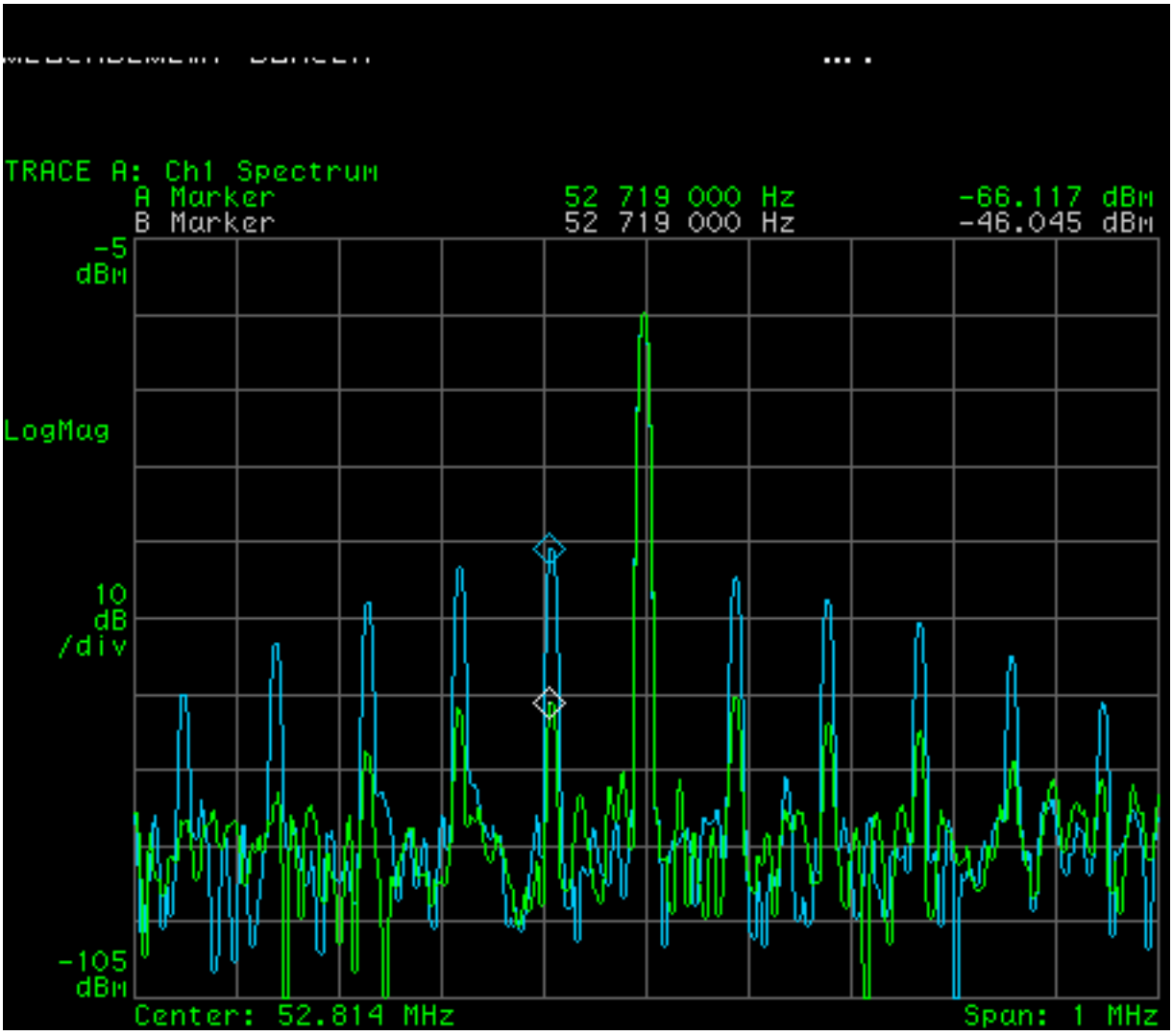
Future Projects

Beam Loading Compensation up the Ramp: Applying Feedforward Compensation up the Ramp on a Pbar Stacking Cycle is expected to help us reduce the longitudinal emittance blow-up (especially through transition).

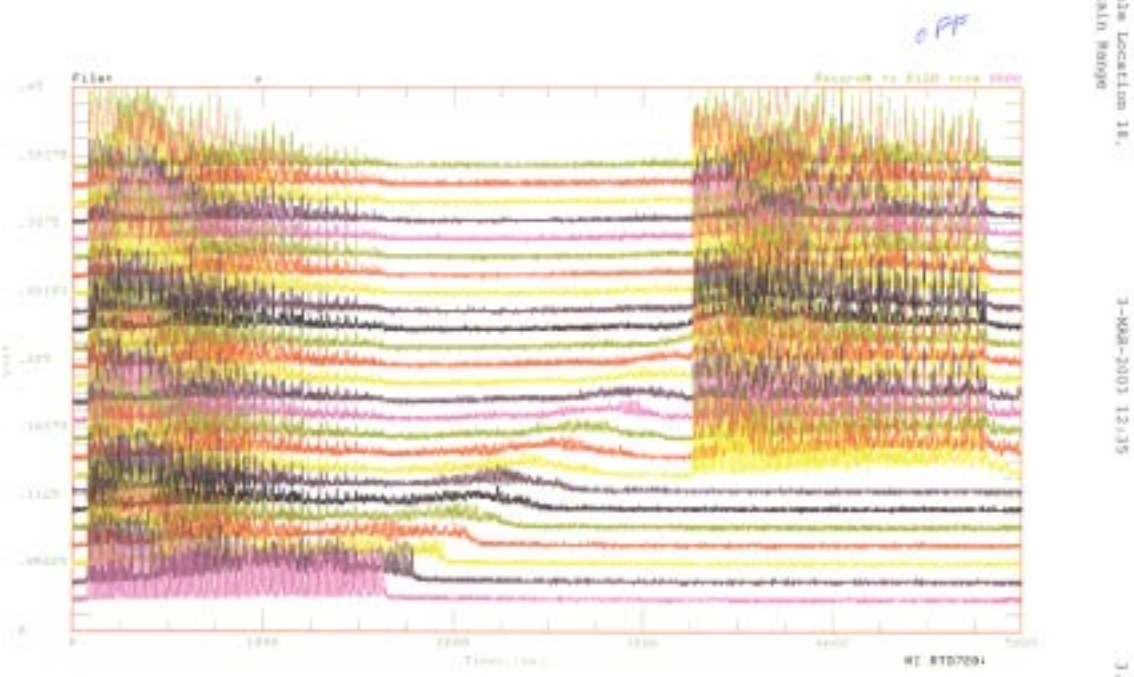
Slip Stacking: Beam Loading Compensation requirements for Slip Stacking will require a change in the operation of the Cavity Power Amplifier from Class C to Class A and may require the purchase of additional solid-state amplifiers.



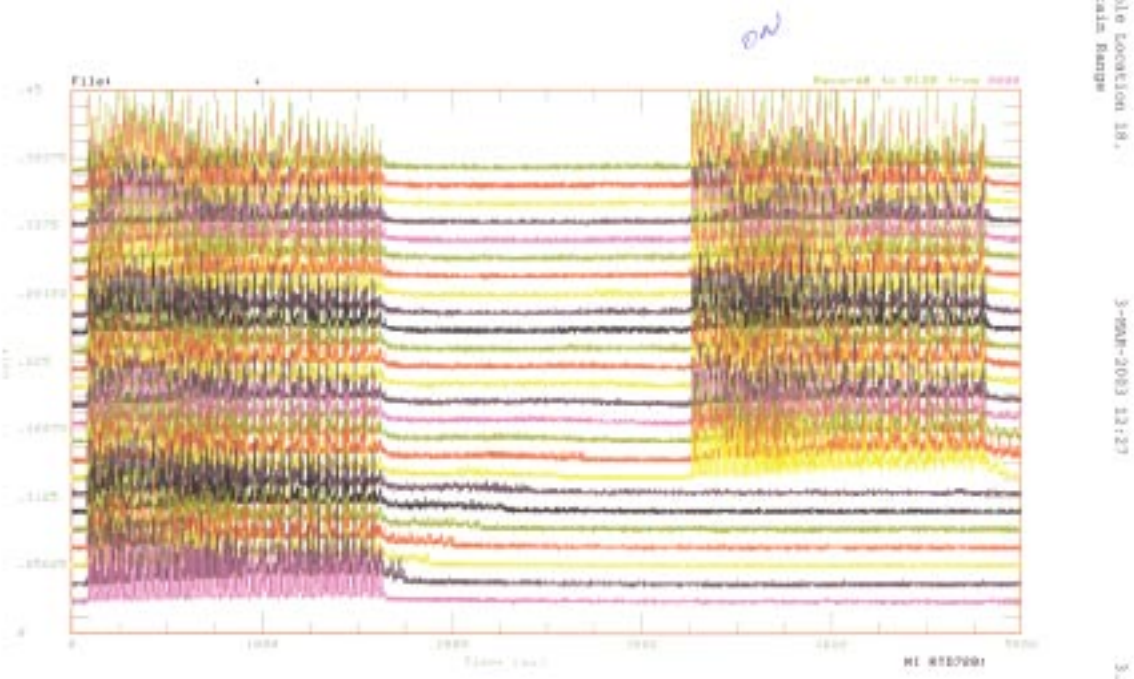
MI Cavity Beam Loading at 8 GeV
Blue: 84 Proton Bunches
Green: 7 Proton Bunches



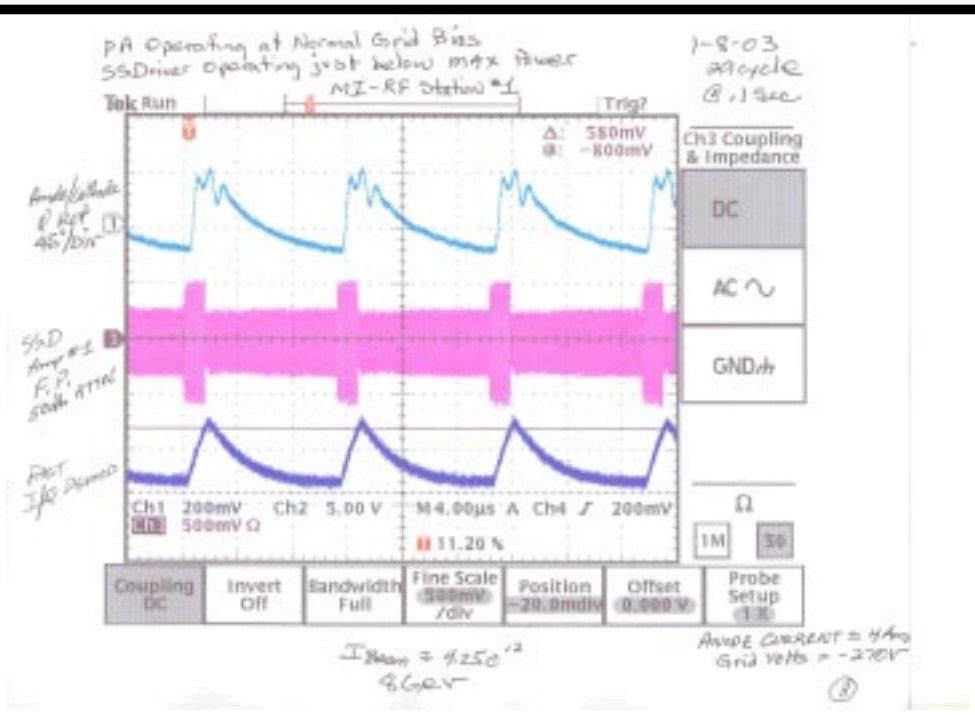
Feedforward BLC of
84 Proton Bunches at 8 GeV
with Power Amplifier in Class A



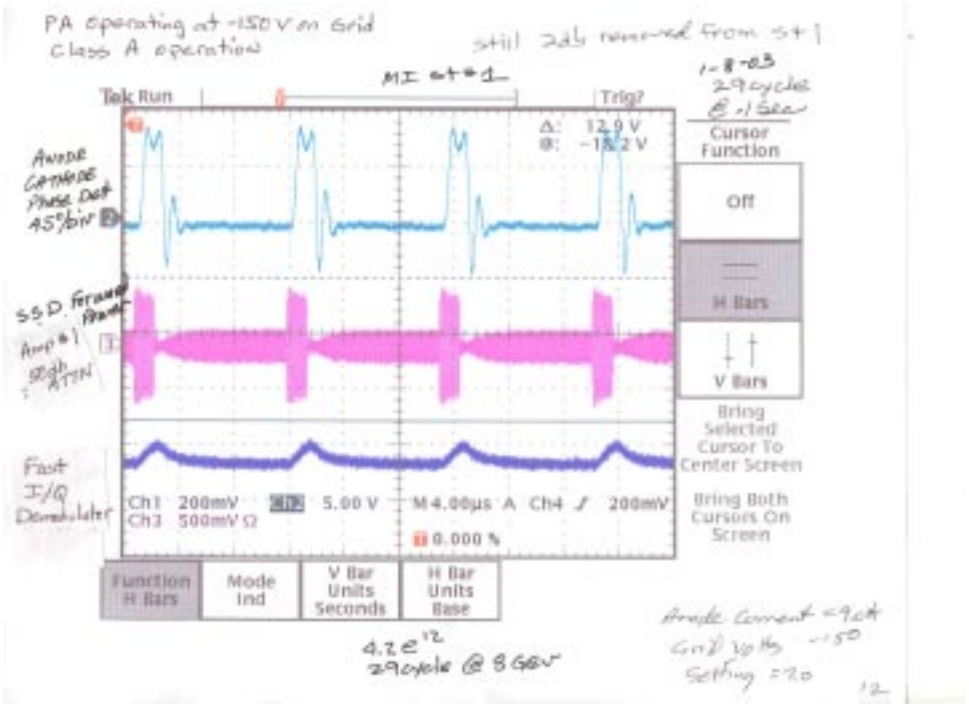
Slip Stacking with
Feedforward BLC Off



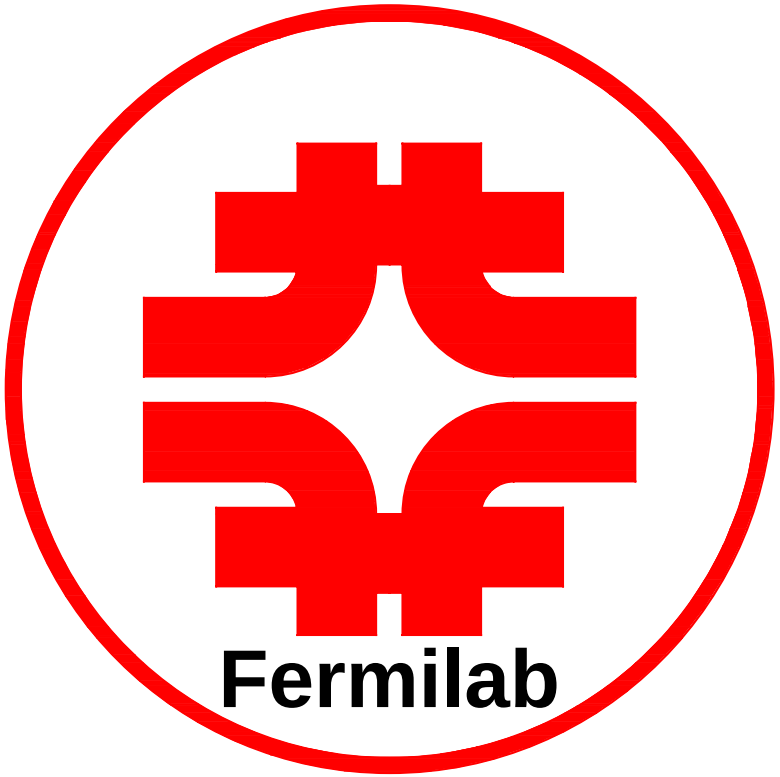
Slip Stacking with
Feedforward BLC On



Slip Stacking Feedforward BLC with Power Amplifier in Class C



Slip Stacking Feedforward BLC with Power Amplifier in Class A



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